U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Demonstration of Advanced Technologies for Multi-Load Washers in Hospitality and Healthcare – Wastewater Recycling Technology

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The Department of Energy coordinates technology demonstrations with the General Service Administration's Green Proving Ground program: GSA website. The Green Proving Ground leverages GSA's real estate portfolio to evaluate innovative sustainable building technologies and practices, while the Department of Energy-funded technology demonstrations are conducted in both federal and non-federal buildings. Findings are used to support the development of technology performance specifications and inform decision-making within federal agencies and the real estate industry. The programs aim to drive innovation in energy and environmental performance in buildings and help lead market transformation through deployment of new technologies. Learn more at: http://energy.gov/eere/buildings/technology-demonstrations#propose

GPG Green Proving Ground Program

Disclaimer

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I. Executive Summary

The U.S. Department of Energy (DOE) Building Technologies Office seeks to develop and accelerate the integration of energy efficient technologies and solutions into new and existing buildings. An area of interest is multi-load washers used in the healthcare and hospitality industry because they are among the most energy intensive pieces of equipment used in these facilities. Multiple technologies are available on the market for significantly reducing energy and water consumption of multi-load washers. However, adoption of these advanced technologies has thus far been limited because of uncertainty about return on investment and concerns about reliability, performance, and user satisfaction, including hotel guest/healthcare patient satisfaction. Quantifying the energy and water savings potential of current market-ready systems will help promote the adoption of these technologies in the commercial sector.

The objective of this demonstration project was to evaluate market-ready retrofit technologies for reducing the energy and water use of multi-load washers in healthcare and hospitality facilities. Specifically, this project evaluated laundry wastewater recycling technology in the hospitality sector and ozone laundry technology in both the healthcare and hospitality sectors. This report documents the demonstration of a wastewater recycling system installed in the Grand Hyatt Seattle. The ozone laundry technology evaluation is documented in a separate report. [1]

In addition to quantifying the savings offered by this technology, the project also endeavored to characterize the relative satisfaction of the performance of the wastewater recycling system. Overall satisfaction was gauged based on discussions with laundry staff and engineering, including ease of integration, and operation and maintenance of the technology, as well as, consistency of the condition of the laundry and whether there was any change in customer complaints.

Laundry wastewater recycling is an add-on retrofit technology to improve energy and water efficiency in commercial laundries. In addition to the limiting factors to widespread adoption previously mentioned, space requirements and capital cost are considerations for this technology. The system works by initially cleaning the wastewater discharge from the laundry system through a series of filtration steps designed primarily for removing solids, followed by several stages of disinfection. The cleaned water is sent to a holding tank, where it is continually disinfected with oxidizing agents until it is needed for the next wash cycle, at which point it is further disinfected with ultraviolet light and sent back to the laundry system washers.

After the initial installation and startup period, systems typically require little maintenance apart from filter replacements. Wastewater recycling has little to no impact on wash quality, and can be used in all commercial facility types, regardless of the degree of laundry soiling.

AquaRecycle™, located in Marietta, Georgia, supplied the wastewater recycle system at the Grand Hyatt Seattle at an approximate installed cost of $100,000. The recycling system was already in place prior to this project,

[1] WJ Goetzler, TA Sutherland, KJ Foley, BK Boyd, GB Parker, GP Sullivan, JM Petersen, 2014. "Demonstration of Advanced Technologies for Multi-Load Washers in Hospitality and Healthcare – Ozone Laundry Systems." Prepared by Navigant Consulting, Inc. on behalf of Pacific Northwest National Laboratory for the U.S. Department of Energy, Washington, DC.

therefore, the baseline was developed by measuring the temperatures and flow rates of the recycled water returned to the washing machines. In the true baseline this water would have been supplied by make-up water, at make-up water temperatures. As such, the volumetric flow and the embodied energy of this system-return, serves as the net energy and water benefit to the installation, and thus the savings.

The results of this evaluation are based on data collected from November 2013 to February 2014. During that time the wastewater recycle system saved an average of 365 thousand gallons/month of combined water and sewer and 1,119 therms/month in hot water heating energy, while adding an electrical load of 1,922 kWh/month. In this case, the source of hot water is a heat-exchange process using distributed hot water generated by city steam with a heat exchange efficiency of 94% (according to the site). Scaling the three-month evaluation values based on average annual occupancy allows for the calculation of an extrapolated annual savings.[2] Table 1 shows the extrapolated annual results of the Grand Hyatt Seattle demonstration considering their electrical rate of $0.072/kWh, a combined water and sewer rate of $22.99/thousand gallons (kgal), and a hot water heating rate of $1.10/therm. The results show the system increases laundry electricity consumption, while providing significant water savings and reducing hot water energy requirements. Hot water heating in this case comes from steam which is provided by Seattle Steam, which generates the steam using natural gas as the fuel. In addition to the savings provided, laundry staff and facility engineering noted the technology integration went smoothly and overall customer satisfaction of the linens remains high, which is imperative given the status of the Grand Hyatt Seattle.

Table 1. Grand Hyatt Laundry Water Recycle Extrapolated Annual Evaluation Results‡

Utility Component	Utility Savings (unit/year)	Utility Rate	Net Monthly Savings ($/year)
Electricity	(27,220) kWh	$0.072/kWh	($1,960)
Water/Sewer	5,175 kgal	$22.99/kgal	$118,973
Hot Water	15,850 therms	$1.10/therm	$17,435
Total Net Savings $/year			**$134,448**
Simple Payback Period			**0.7 years**

‡ Based on 280,000 pounds of laundry/month and a wastewater recycle system cost of approximately $100,000.

Conclusions

The Grand Hyatt Seattle is characterized as having relatively high utility rates—especially water and wastewater rates. The wastewater recycle system projects to save 5,175 kgal of water/sewer and 15,850 therms of hot water heating energy annually while adding an electrical load of 27,220 kWh to operate the system. The result is significant net utility cost savings and a simple payback period of less than 1 year for the Grand Hyatt Seattle. The evaluation shows this technology could be financially attractive for hotels with similar laundry volume and similar utility characteristics. It also shows the system can be integrated at a high-end hospitality facility without negatively impacting the operation of the central laundry or the quality of the linens being laundered.

[2] Typical occupancy is 82.2% of capacity and the occupancy rate during the evaluation averaged 69.6% of capacity. Therefore the annual numbers were scaled by multiplying the utility consumption by 1.18 (82.2/69.6) to accurately project true annual consumption/savings.

II. Introduction

Most institutional laundry systems found in on-premises hospitality and healthcare facilities are batch multi-load washers (MLWs) and washer extractors with thousands of pounds of throughput daily. MLWs and washer extractors are among the most energy intensive equipment in hotels, consuming 60% to 70% of all hot water used.

Improvements in efficiency in batch laundry MLWs are available from system improvements or retrofits. These retrofits are commonly either 1) a low-temperature chemical-reducing ozonation system replacing traditional hot water-based detergents, or 2) a wastewater recycling system that reduces hot water consumption.

For example, a field demonstration project in a commercial hotel laundry was undertaken by Pacific Northwest National Laboratory (PNNL) in a Red Lion Hotel in Portland, Oregon. The laundry serves a large hotel/motel chain and processes an average of 25,000 pounds of laundry per day. A wastewater recovery system was installed in the laundry in September 1995. After approximately 5 months, the retrofit system had achieved final results of 52% savings in water consumption and 44% savings in energy to heat water. In this case study, performance measurements show monthly savings of approximately $3,400 on water, sewage, and natural gas resulting in a simple payback of 4.1 years (Garlick et al, 1996).

Several studies of ozonation retrofit systems have been undertaken by utilities offering incentives for ozone system retrofits and by the ozone equipment manufacturers/installers. A large chain hotel achieved more than a 90% reduction of hot water use in their laundry facility after an ozone system was installed, resulting in more than 9,000 therms/yr. of natural gas savings with an additional savings of 2,000 therms/yr. in dryer energy use for the facility.[3] The data were provided by the manufacturer/installer of the ozone system (Wyndham 2010).

A 2009 DOE study performed by Navigant Consulting, Inc. (Navigant) estimated industry-wide potential savings of 124 trillion British thermal units per year (Btu/yr.) as a result of efficiency retrofits in institutional laundry systems (Zogg et al. 2009). This estimate was based on nationwide utility consumption estimates rather than throughput or turns per day. This technical potential is based on an estimated primary annual energy consumption of 248 trillion Btu/yr. and roughly 50% savings per unit with wastewater recycling systems or low-temperature detergents, which is consistent with the Red Lion field demonstration.

Recognizing that both ozonation and wastewater recycling retrofits in MLWs can deliver significant energy and water savings**,** DOE funded a demonstration of these energy-efficiency measures through the Better Buildings Alliance (BBA) to further examine the potential savings. DOE demonstrations were considered important and necessary to provide rigorous and independent measurements of the energy and water savings of retrofitted systems.

Despite marketing efforts and financial incentives by some energy and water utilities the hospitality and healthcare industries are not widely adopting and embracing these technologies because of uncertainty about return on investment and concerns about reliability, performance, and customer satisfaction. Therefore, these DOE-led demonstrations will quantify the water-heating energy savings as well as water

[3] Ozone opens up the fibers and makes the linens easier to dry and can result in decreased drying times.

savings, ascertain the user and customer satisfaction, and allow the industry to estimate its return on investment (ROI) and/or life-cycle cost savings of installing these measures.

III. Project Scope

The scope of this project is to quantify the energy and water savings potential of wastewater recycling systems and ozonation/low-temperature detergent supply systems to help accelerate the adoption of these technologies in the commercial sector across not only the hospitality and healthcare industry, but all sectors that employ MLWs. In addition to quantifying the savings offered by this technology, the project also endeavored to characterize the relative satisfaction of the performance of the wastewater recycle system. Overall satisfaction was gauged based on discussions with laundry staff and engineering, including ease of integration, and operation and maintenance requirements, as well as, consistency of the condition of the laundry and whether there was any change in customer complaints.

The objective for this project is to enable widespread technology transfer in the industry and specifically among the Commercial Buildings program's BBA members. Possible follow-on activities include the development of general technical specifications of efficient multi-load laundry equipment that are tailored for specific applications and/or sectors (hospitality, healthcare, etc.), vetted with the hospitality and healthcare partners and other BBA partners, finalized, published, and disseminated.

Three sites were selected to undertake field demonstrations of the energy and water savings of retrofit technologies: a hotel in Seattle WA, a hotel in Charleston SC, and an assisted living facility in Boston, MA. This report documents the demonstration of a wastewater recycling system installed in the Grand Hyatt Seattle. The ozone laundry technology evaluation was performed at the Charleston Place Hotel in Charleston, SC and the Rogerson House in Boston, MA and is documented in a separate report. [4]

At each demonstration site, a plan was developed to meter and monitor all relevant system inputs and to collect non-metered/monitored data. [5]

Utility rates for each demonstration site were determined to aid in the economic analysis. These included electricity rates from the rate schedule(s), natural gas rate from the rate schedule(s), supplied steam rate, and water supply and wastewater treatment rates from the rate schedule(s).

Laundry system data collection included:

- Equipment energy use including
    - Electrical energy of ozone generator
    - Natural gas (or electric) for water heating
    - Electrical energy use of washer
    - Steam for heating water

[4] WJ Goetzler, TA Sutherland, KJ Foley, BK Boyd, GB Parker, GP Sullivan, JM Petersen, 2014. "Demonstration of Advanced Technologies for Multi-Load Washers in Hospitality and Healthcare – Ozone Laundry Systems." Prepared by Navigant Consulting, Inc. on behalf of Pacific Northwest National Laboratory for the U.S. Department of Energy, Washington, DC.
[5] The methodology and results of the technology analysis are described in the scoping report, found here: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22310.pdf. Note that the metering approach and test plan described in the scoping report were subject to change due to individual site-specific circumstances.

- Equipment water use including
    - Cold water volume and temperature
    - Hot water volume and temperature
- Equipment total usage including
    - Washer cycles per period (tracked daily, weekly, or monthly)
    - Washer cycle selection – if possible track type of cycles to match pre and post periods for consistency
    - Other use (non-metered) data collected, including
        - Chemicals (detergent, fabric softener, etc.) use
        - Throughput (e.g., pounds of laundry processed per month)

In addition, data were collected on the user (facility laundry staff) and customer satisfaction, including but not limited to overall user satisfaction of the retrofit system, observations of operations of the retrofit system (e.g., did the operations of the laundry system change with the retrofit), maintenance of the laundry system before and after retrofit, condition of the laundry before and after retrofit (e.g., any changes in color, fabric wear, etc. after retrofit of the system), and customer (hotel guests, residents) feedback, if any.

The results of the demonstration will be reported and widely distributed throughout the BBA and industry in general. Case studies will be developed and disseminated to highlight the technologies, technology applicability/acceptance, the energy (and water) savings potential, and the cost savings.

Technical specifications will be developed for potential use by the BBA stakeholders to consider procuring new/retrofit applications. The specifications can also be used to promote water/energy utility incentives in markets where there are currently no incentives for these technologies. These materials will be vetted and distributed through DOE to the BBA stakeholders and members and others in multiple venues, as one element to help transform the industry to adopt efficient technologies.

IV. Project Approach

This project was jointly undertaken by PNNL and Navigant, with PNNL responsible for overall project management as well as leading the wastewater recycle demonstration described in this report.

The general approach taken to select the demonstration sites and retrofit systems for the demonstration was multifaceted. The initial decision of the project team was to divide the demonstrations geographically, with Navigant taking the lead for potential demonstration sites in the eastern part of the country (east of the Mississippi) and PNNL taking the lead for demonstrations west of the Mississippi. It was also desired to undertake at least one demonstration in the hospitality sector and one demonstration in the healthcare sector, so both target sectors would be represented.

A. Identifying and Selecting Retrofit Technologies

The project team initially considered four multi-load washer technologies for this project:

1. Laundry wastewater recycling
2. Low-temperature detergents
3. Ozone technology
4. Polymer bead technology

For each technology, the team investigated water and energy savings, technology development status, market availability, and number of providers of the technology. The team also considered other notable aspects such as installation requirements, operational requirements, and suitability for use in healthcare or hospitality facilities. The results of this analysis indicated that laundry wastewater recycling and ozone technology would be the most suitable for this demonstration project.

Specifically, wastewater recycle emerged as an appropriate technology choice due the following characteristics:

- High potential energy and water savings
- Mature but underused technology
- Readily available on the market from multiple vendors
- Relatively low market penetration
- Retrofit technology compatible with almost any multi-load washer
- Little or no additional training required for operation

Laundry wastewater recycling works by initially cleaning the wastewater discharge from the laundry system through a series of filtration steps designed primarily for removing solids, followed by several stages of disinfection. The cleaned water is sent to a holding tank, where it is continually disinfected with oxidizing agents until it is needed for the next wash cycle, at which point it is further disinfected with ultraviolet light and sent back to the laundry system washing machines. After the initial installation and startup period, systems typically require little maintenance apart from filter replacements. Wastewater recycling has little to no impact on wash quality, and can be used in all commercial facility types, regardless of the degree of laundry soiling.

B. Vendor and Site Selection

Parallel tracks were taken to identify and select candidate sites, including:

- Contacting the lead at DOE for the BBA Commercial Real Estate & Hospitality and Healthcare peer groups to make them aware of the search for a demonstration site and seek support for assisting in the identification of candidate sites. The team developed a flier to hand out to the peer groups at appropriate venues and for posting on the BBA web site. A copy of the flier is included in Appendix D.
- Identifying and contacting vendors of each technology to ascertain their interest in participating in a demonstration. This approach would allow the team to monitor an already-planned installation, thus saving the expense of purchasing the technology. Initial contact was by phone with a follow up of information on the project including the flier developed for the DOE BBA members. The team developed a set of vendor engagement talking points to be used during the initial phone contact to provide information about the demonstration. Twelve vendors (9 ozone, 3 wastewater recycle) were initially contacted and screened for their interest. Those indicating interest were pursued.
- Ascertaining the intersection of the following key criteria: 1) interested vendors with current or planned retrofit projects (including willingness of the vendor to allow metered data to be published); 2) type of technology (ozone or wastewater recycle); 3) location of those projects; 4) timing of those projects; 5) whether or not the planned projects are in a hospitality or healthcare

facility. Of these considerations, the timing of the project was most important given the limited window for monitoring/metering and the desire to baseline the existing laundry system prior to installation of the efficient technology.

The approach resulted in several vendors interested in cooperating in a demonstration, with candidate sites identified that met the monitoring window and in convenient geographical areas for PNNL and Navigant to cost-effectively undertake a demonstration.

There were multiple candidate sites for demonstrating the ozone technology but only one site that met the key criteria for demonstrating the wastewater recycle technology, and it was in the PNNL geographical area. For this candidate site the retrofit system was recently installed by AquaRecycle™. Therefore, before selecting this site, there was careful consideration and significant discussion about how to quantify the baseline conditions given the system was installed prior to the start of the evaluation project. It was determined that the baseline could be adequately characterized using historical metered data and thus, the Grand Hyatt Seattle in downtown Seattle, WA was determined to be viable.

This report presents the results of the wastewater recycle demonstration at the Grand Hyatt Seattle. The ozone systems demonstrations are presented in a separate report.

C. Executing Access Agreements

A host site agreement was executed with the Grand Hyatt Seattle to allow access to install equipment and to record data. No work could take place until an agreement was signed by all parties. The site agreement described the terms and conditions of the demonstration, including responsibilities and host site commitments. A copy is included in Appendix E.

V. Demonstration Description

A. Site Description

This program was designed to evaluate a laundry water recycling system as installed at the Grand Hyatt Seattle in Seattle, WA. The Grand Hyatt, a four diamond hotel located in downtown Seattle, has 425 guest rooms, 3 restaurants, and over 25,000 square feet of conference space. In addition to the Grand Hyatt, laundry from Hyatt's nearby Olive 8 property is also processed in the Grand Hyatt Seattle laundry facility. The Olive 8 is a full-service hotel and has 346 guestrooms and 12,000 square feet of function space.

The Grand Hyatt Seattle laundry facility makes use of five hard-mount Alliance Laundry/Speed Queen commercial washers. This equipment serves the laundry needs of all guest rooms (towels, sheets, etc.) and conference rooms (table linens, etc.) from the two Hyatt hotels, processing about 280,000 pounds of laundry monthly.

Utilities used by the Grand Hyatt Seattle laundry facility include electricity (pumps, motors and controls), purchased steam (water heating) and water/wastewater. Table 2 presents the average utility costs reported during the period of the demonstration. There may be some variability to these costs as utility rate structures can change with seasonal rates, use blocks, and market pricing variables. These values were developed to represent the average marginal utility rates.

Table 2. Grand Hyatt Seattle Marginal Average Utility Rates

Utility Type	Serving Utility	Unit Rate	Notes
Electricity	Seattle City Light	$0.072/kWh*	Based on January 2014 Large Network General Service Rate
Purchased steam	Seattle Steam	$1.10/therm	Based on 2014 rate schedule for Rate 23 contracts
Water	Seattle Public Utilities	$7.42/kgal‡	Based on 2014 General Services Commodity Charges
Sewer	Seattle Public Utilities	$15.57/kgal‡	Based on 2014 General Services Commodity Charges

*This represents the average marginal rate for electricity

‡ kgal represents thousands of gallons

B. Existing Laundry System Description

The Grand Hyatt Seattle laundry facility processes about 280,000 pounds of laundry monthly. The facility uses five hard-mount Alliance Laundry/Speed Queen commercial washers: two 165 lb., two 135 lb., and one 55 lb. These washers receive cold water from a dedicated connection and hot water from a steam-to-hot-water heat exchanger. Figure 1 shows one of the Speed Queen 135 lb. machines.

Figure 1. Grand Hyatt Speed Queen 135 Pound Washer (Photo: PNNL)

The Grand Hyatt's water recycle system was installed in 2013 and is a skid-mounted, fully contained system constructed, installed and serviced by AquaRecycle™ of Marietta, GA. This system can be installed as new construction or as add-on retrofit technology, in the case of the Grand Hyatt Seattle, this was a retrofit application. Because this system was installed prior to the start of the evaluation project, a true baseline analysis was not possible.

The recycle system functions by first pumping the wastewater to a holding tank from where it is pumped to a lint removal vibration system for removal of all large solids in the process water. Next, a pump sends the filters water through pressure filters to remove suspended solids, oil/grease, soaps and other organics. This water is then sent to the water recycle tank. Prior to being re-injected into the wash system, an ultra-violet and ozone disinfectant systems is used to kill all bacteria before the water goes back into the washing process.

The system components that consume energy include the numerous pumps, lint removal, and disinfecting systems. Similar to other recycle systems, the fully automated filtration systems allows for simple deployment and monitoring of the individual peripherals. A picture and schematic of the AquaRecycle™ system are shown in Figure 2 and Figure 3, respectively.

Figure 2. AquaRecycle System (Photo: PNNL)

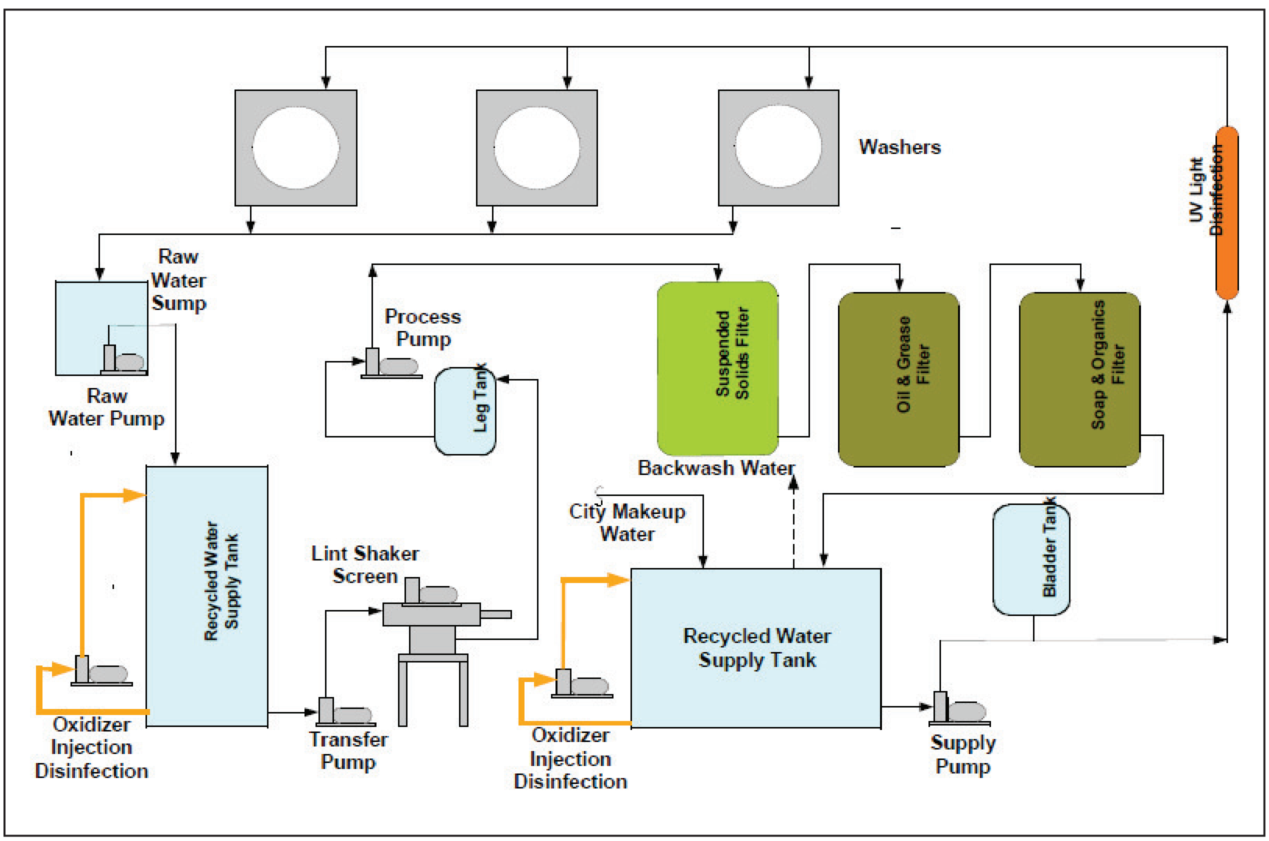

Figure 3. Schematic of AquaRecycle System

VI. Demonstration Approach

The goal of this demonstration is to evaluate the energy and water use, saving, and economics of commercially available water recycle system. Customer and system operator satisfaction is a key to market acceptance. Input from site staff on system operation, performance, maintenance needs, and overall satisfaction was requested and is summarized in this report.

A. Metering Overview

Because the recycling system was existing (i.e., had already been installed prior to this project), the metering protocol was developed to include an analysis to account for the savings from a "technical" baseline. This baseline was developed using additional metering to measure temperatures and flow rates of system-return water. In the true baseline this water would have been supplied by makeup water, at makeup water temperatures. As such, the volumetric flow and the embodied energy of this system-return, serves as the energy benefit to the installation, and thus the savings.

The specific metering objectives are listed below:

- Evaluate hot/cold water and *energy use* for the AquaRecycle™ laundry waste water recycling system, including the development and calculation of the technical baseline.
- Evaluate hot and cold water and *energy saving* associated with the AquaRecycle™ laundry waste water recycling system.
- Evaluate clothes washer utilization (average cycles and/or pounds washed per period).
- Present the water, energy, and economic findings.

B. Metering and Monitoring Approach

A description of each monitored parameter is included below. Monitoring took place at the recycling system and the serving electrical subpanel. All monitored data were collected by standalone data loggers dedicated to the specific metering components. A description of the metered parameters includes the following:

System Water Use: Water use was monitored by non-intrusive EMCO Sono-Trak ultrasonic flow meters at two locations:

- Cold makeup supply flow to the water-recycle system
- Recycled water from the system to the washers

The flow meters were installed on the copper supply/return lines. This is a proven installation technique and, because it does not affect existing piping (i.e., the meters reside on the exterior of the piping), it eliminates the need for a plumber's intervention. The meters provided a continuous data use record of water flow to the data loggers where it was stored in a 1-minute time-series format.

System Water Temperature: Water temperatures were monitored using thermocouples attached to the warm water supply (from the recycling system) and the cold makeup water. The thermocouples provided the temperature data to data loggers where it was stored in a 1-minute time-series format.

System Electrical Energy Use: Electrical energy use (recycle-system electricity for pumps, motors, shaker/lint system, UV light, and all controls) was monitored by a watt transducer installed at the serving electrical panel. The watt transducer provided pulse-output wattage data (pulses calibrated to know kWh value) to the data logger where it was be stored as the other metrics.

System (Clothes Washer) Utilization: The total number of pounds of laundry washed was recorded by site staff and reported on a monthly basis. These data become instrumental in process of normalizing the savings to develop metrics useful for other sites.

Data Collection and Storage: The data loggers used to record and store the temperature, energy, and water use data were downloaded on-site at roughly a monthly interval.

Further information on the metering and evaluation monitoring plan is available in Appendix B.

C. Non-Metered Data

In addition to technical data, the team held informal discussions with the laundry operations staff to determine overall satisfaction with the AquaRecycle system. End-user and customer satisfaction is important to successfully transforming the industry to adopt and retrofit multi-load laundry systems with higher-efficiency technologies. The team was also able to assess the following through discussion with site personnel:

- Overall cleaning performance – Has the cleanliness of the laundry changed as a result of the wastewater recycle system?
- Ease of operation – Have the operating characteristics of the laundry system changed pre- and post-system installation and if so, what are those changes?
- Human resources – Has there been a change in labor or maintenance requirements and staffing pre- and post-system installation and if so, what are those changes?

VII. Results

The results of this evaluation are based on data collected over a 3-month period, November 2013 to February 2014. Data were recorded by the loggers at 1-minute intervals to allow better resolution and evaluation. Over the 3-month period, more than 500,000 data points were collected and analyzed.

A. Electrical Energy Use

The electrical energy use of the recycling system comprises a variety of pumps, motors, UV lights, and controls. The sum of these loads was metered at the breaker panel serving the recycling system.

Figure 4 presents the daily electrical energy use (kWh/day) of the recycling system. The noted variance in daily energy use relates to variability in washer use (i.e. laundry processed) at the laundry facility. The average daily electrical energy use was 63.2 kWh/day. This electrical use is specific to the recycling system, and because this is an added use to the overall laundry system, there is no “baseline” energy to compare this to. This electrical energy use and its resulting economics count against the savings from this system.

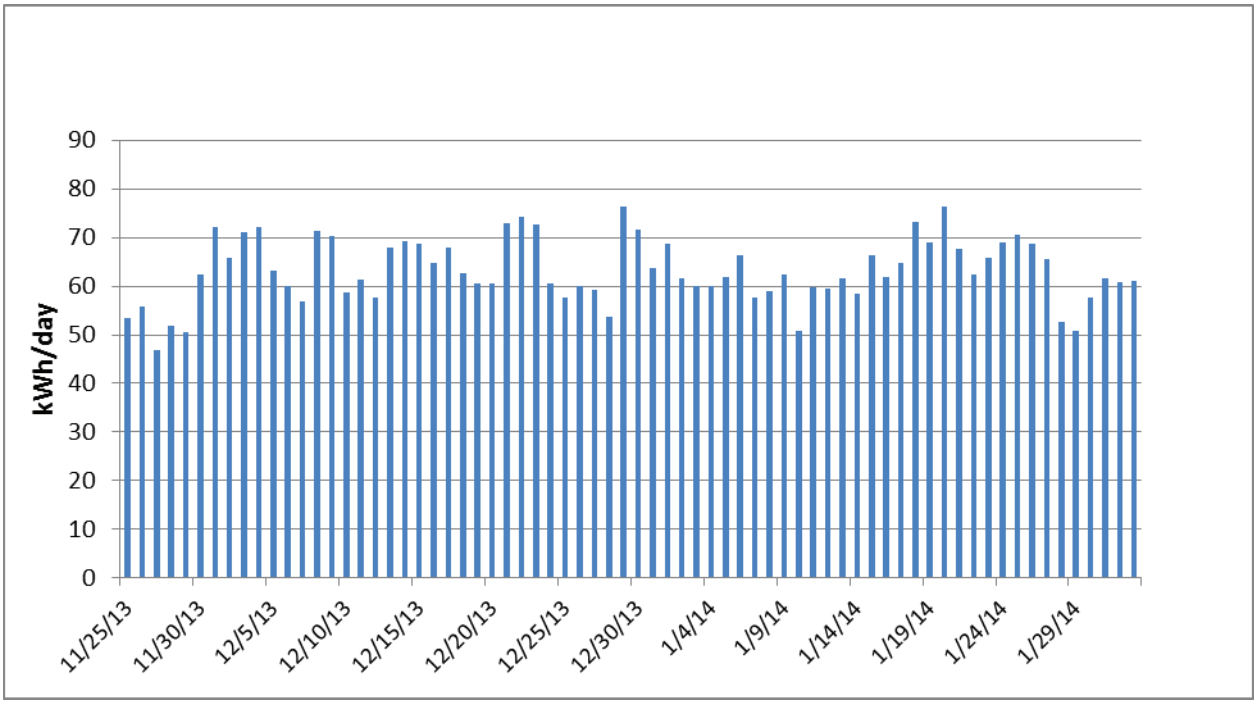

Figure 4. Wastewater Recycling System Daily Electricity Use

B. Water Savings

The water savings of the recycling system result from its ability to capture the discharge water from the laundry operation and then process, clean, and disinfect it. Once cleaned and disinfected, the water is re-heated, and returned to the washers thus displacing the need for fresh water. For each gallon of recycled water, a gallon of city fresh water does not get used – or paid for in water and wastewater charges.

Because the recycling system was installed prior to the start of this demonstration, the evaluation team did not have the ability to generate a metered water-use baseline. However, because the installed metering captured both supply and recycled water use, an engineered baseline (i.e., calculated baseline) could be developed. The engineered baseline represents the sum of all supply and recycled water. In essence, this engineered baseline is the water use in absence of the recycling system.

Figure 5 presents the engineered baseline daily water use. As with the electrical use, the variance in daily energy use relates to variability in washer use (i.e. laundry processed) at the laundry facility. The average daily baseline water use for the evaluation period was 14,990 gallons/day.

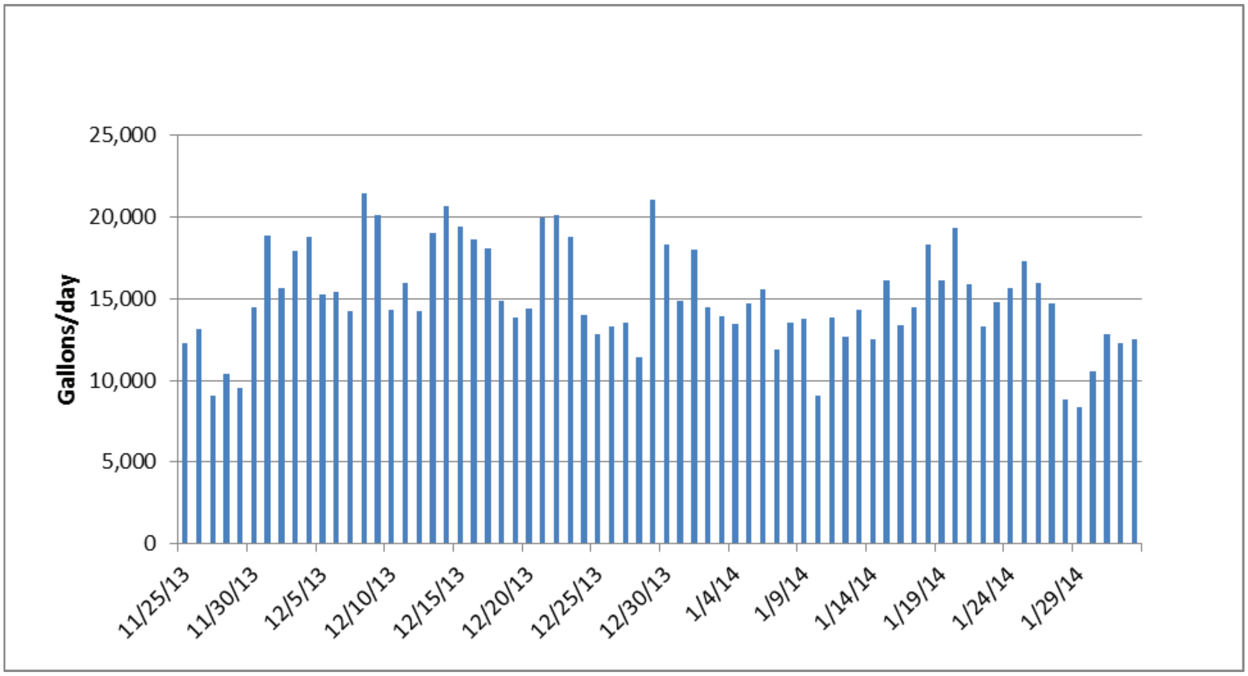

Figure 5. Wastewater Recycling System Daily Baseline Water Use

Figure 6 presents daily recycled water processed. As expected, these values change with variability in laundry processing. Important in these data are the daily use totals that represent the recycle system water savings. The average daily recycled water processed and thus average system water savings was 12,015 gallons/day.

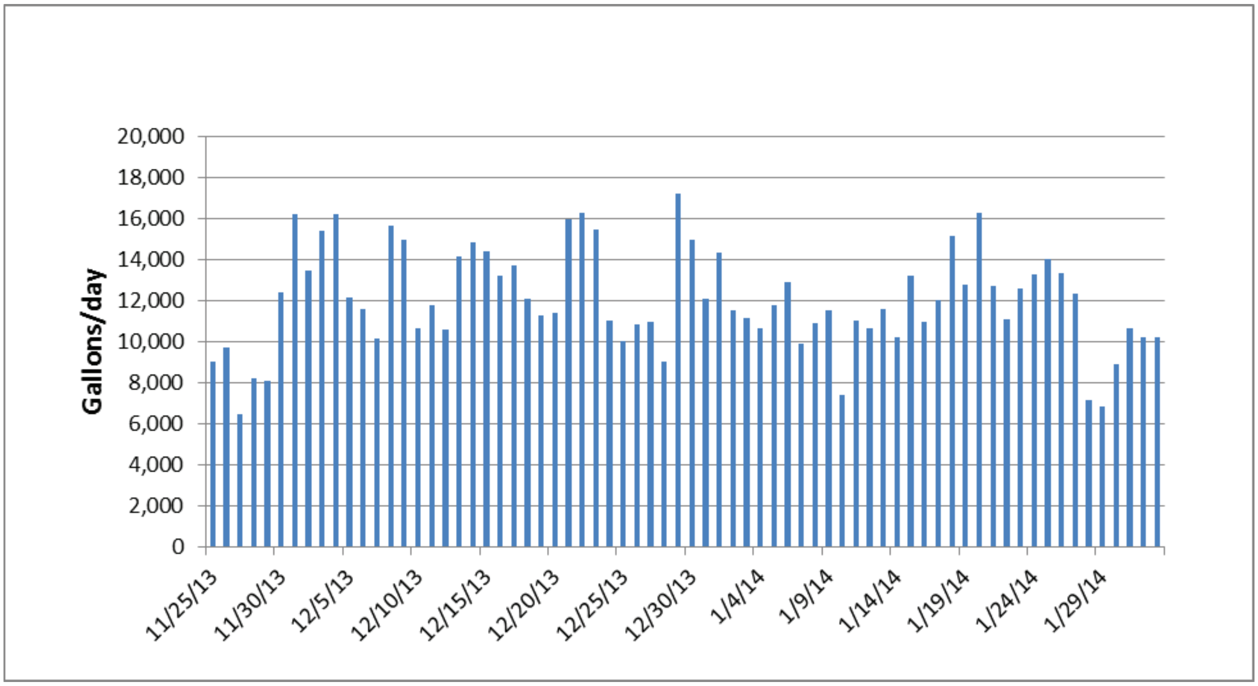

Figure 6. Wastewater Recycling System Daily Recycled Water Processed

Figure 7 highlights the relative use (baseline) and savings (recycled) as calculated for the recycle system.

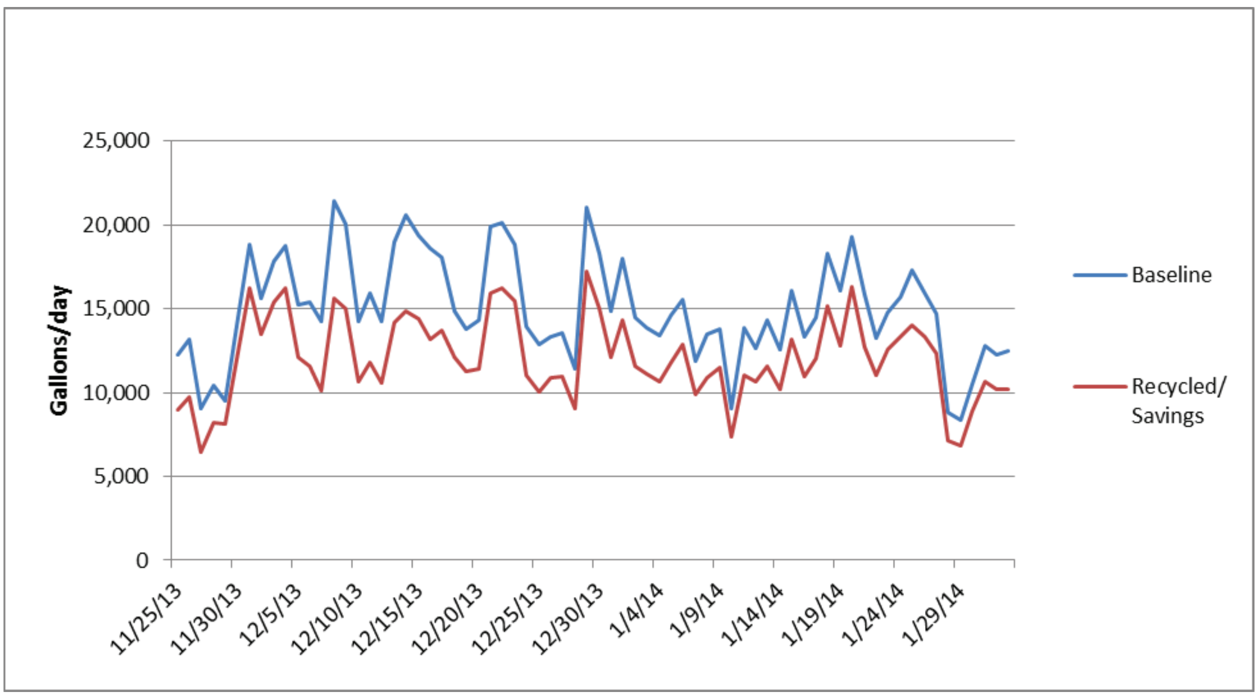

Figure 7. Wastewater Recycling System Daily Baseline and Recycled Water

C. Water Thermal Energy Savings

Embodied in the water saved (i.e., recycled water) is the thermal energy associated with the wash cycle. To capture this energy and calculate the relevant savings, thermocouples were installed at the water recycle system and on the city supply water. Given the recycled water metered flow rate and the difference between the recycle system temperature and the city supply temperature, the energy retained in the recycle water can be calculated. Because the Hyatt's source of hot water is a heat-exchange process using distributed hot water generated by city steam, the calculation used a heat exchange efficiency (94% - site provided) and then converted the energy savings to equivalent therms. Because the metering system was designed to measure the net impact (i.e., the savings), this value does not have a true baseline, thus it is presented as a savings value only.

Figure 8 presents daily thermal energy savings from the recycled system. As expected, these values change with the variability in laundry processing. The average daily thermal energy savings was 36.8 therms/day.

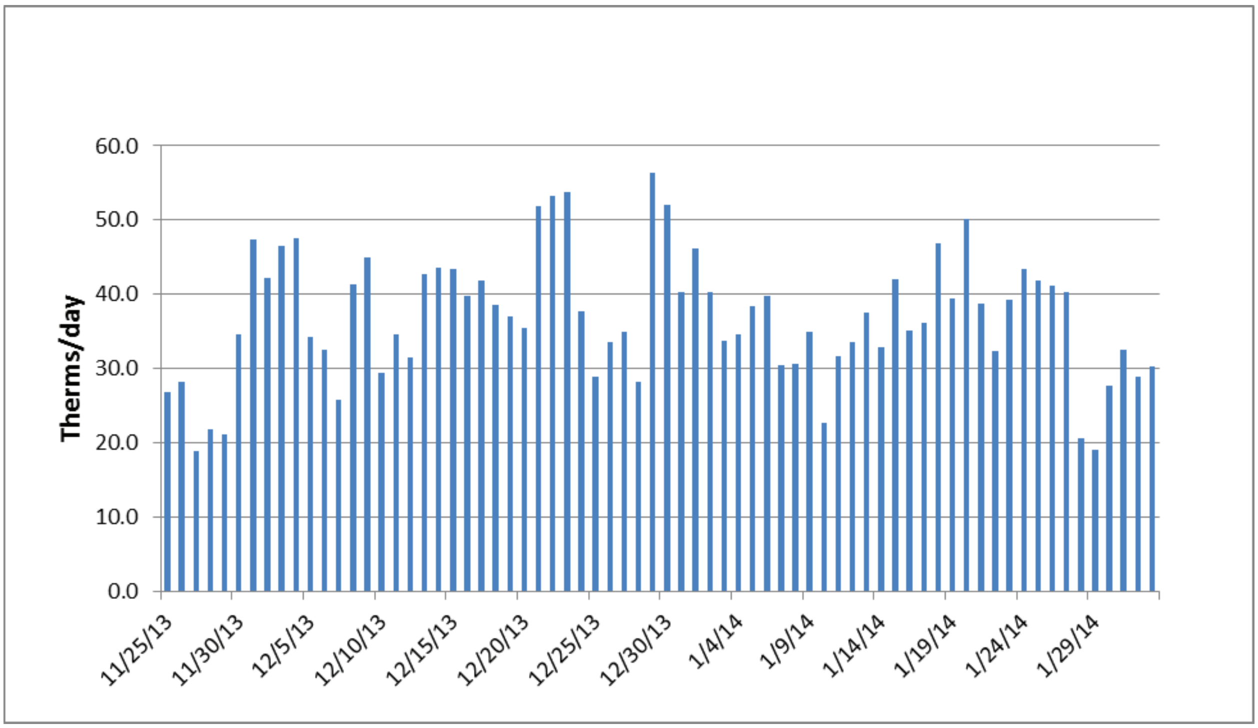

Figure 8. Wastewater Recycling System Daily Hot Water Heating Savings

Table 3 summarizes the results of this evaluation.

Table 3. Grand Hyatt Seattle Laundry Water Recycle Evaluation Results

Utility Component	Baseline Utility Use (unit/month) [1]	Retrofit Utility Use (unit/month)	Utility Savings (unit/month)	Utility Rate	Net Monthly Savings ($/month)
Electricity	NA	1,922 kWh	(1,922) kWh	$0.072/kWh	($138)
Water/Sewer	456 kgal	91 kgal	365 kgal	$22.99/kgal	$8,391
Hot Water	NA	NA	1,119 therms	$1.10/therm	$1,231
Total Net Savings $/month					**$9,484**
[1] Baseline water use and system savings are calculated with metered supply and recycle water flow. Savings reflect water that would have been required in absence of the recycling system.					

Scaling the three-month evaluation values based on average annual occupancy allows for the calculation of an extrapolated annual savings.[6] Table 4 presents the calculated annual savings.

Table 4. Grand Hyatt Laundry Water Recycle Extrapolated Annual Evaluation Results

Utility Component	Utility Savings (unit/year)	Utility Rate	Net Monthly Savings ($/year)
Electricity	(27,220) kWh	$0.072/kWh	($1,960)
Water/Sewer	5,175 kgal	$22.99/kgal	$118,973
Hot Water	15,850 therms	$1.10/therm	$17,435
Total Net Savings $/year			**$134,448**
Simple Payback Period			**0.7 years**

The capital cost for wastewater recycle systems vary greatly depending on capacity and design to meet the necessary water quality requirements. The average capital cost according to AquaRecycle™ is about $100,000. Based on the savings achieved at the Grand Hyatt Seattle and the installed cost of the wastewater recycle system, the technology has paid for itself in less than a year.

Because these savings were developed specific to the demonstration site, and were subject to exogenous variables over the 3-month evaluation window, data normalization was explored to make the data relevant to other facilities. The most appropriate normalization variable for commercial laundry is dry pounds processed. Working with site staff, the team captured the laundry poundage specific to the study period. These data were then used to develop weight-normalized use and savings metrics.[7] Table 5 present these values.

[6] Typical occupancy is 82.2% of capacity and the occupancy rate during the evaluation averaged 69.6% of capacity. Therefore the annual numbers were scaled by multiplying the utility consumption by 1.18 (82.2/69.6) to accurately project true annual savings.

[7] Formulas for these calculations can be found in Appendix C.

Table 5. Grand Hyatt Seattle Laundry Water Recycle Evaluation Weight Normalized Results

Utility Component	Utility Use (unit/klb)	Utility Rates	Net Monthly Cost Savings ($/klb)
Electricity	8.05 kWh/klb	$0.072/kWh	($0.58)/klb
Water/Sewer	1.53 kgal/klb	$22.99/kgal	$35.17/klb
Hot Water	4.99 therms/klb	$1.10/therm	$5.49/klb
Total Net Savings $/klb			**$40.1/klb**

Non-metered Data

In addition to technical data, the team gathered the following non-technical information to determine overall satisfaction with the ozone technology:

- Overall cleaning performance – Linen cleanliness has not been negatively impacted by the AquaRecycle system. There has not been an increase in customer complaints and linen quality continues to meet the expectations of Grand Hyatt Seattle's management and clientele.
- Ease of operation – Once the system was fully integrated and adjustments were made to the chemical detergent program, the AquaRecycle system has worked as anticipated.
- Human resources – No changes were reported in labor or overall system maintenance requirements as a result of the AquaRecycle system installation.

VIII. Conclusions

The Grand Hyatt Seattle is characterized as having relatively high utility rates—especially water and wastewater rates. The wastewater-recycle system provided water/sewer savings of 365 kgal/month and hot water heating savings of 1,119 therms/month while adding an electrical load of 1,922 kWh/month during the evaluation period. This results in a significant net utility cost savings and a simple payback period of less than 1 year indicating this technology is financially attractive for hotels with similar laundry volume and similar utility characteristics. It also shows the system can be integrated at a high-end hospitality facility without negatively impacting the quality of the linens processed in the central laundry.

IX. Projected Savings of Widespread Adoption

The estimated annual laundry processed in on-premises commercial laundry facilities in the U.S. is 60 billion lb. (Zogg et al., 2009). Based on the savings achieved at this demonstration, the maximum savings would be a reduction of 90 billion gallons of water consumption and 300 million therms (30 million Btu) of water heating energy if all systems were retrofit with wastewater recycling systems. These savings are unrealistic; however, as it's safe to assume a portion of the marketplace already has wastewater recycling and other limiting factors such as capital cost or inexpensive water and natural gas prices will impede the adoption of this technology. An optimistic savings target may be installation in 10% of the marketplace, resulting in savings of 9 billion gallons of water and 30 million therms (3 million Btu) of water heating energy if similar results are achieved.

X. Barriers to Widespread Adoption

Based on the knowledge and experience gained throughout the course of this demonstration project, the team identified several barriers that are likely limiting the widespread adoption of efficient technologies across the commercial on premise laundry industry.

Lack of familiarity with the technology: Many laundry facility managers may not be aware of wastewater recycling unless they are actively involved in the commercial laundry industry (by attending trade shows, for example). The lifetime of most commercial laundry equipment spans decades, so in a smoothly running laundry facility, the facility manager is likely to focus on day-to-day operational and maintenance needs, rather than the procurement of new pieces of capital equipment.

Resistance to change: A well-functioning commercial laundry system is a highly-tuned operation involving customized wash cycles with detergent and bleach chemistries tailored to the specific needs of the facility. Laundry facility managers are likely to be hesitant to installing a new technology that would require reprogramming the washing machines, changing the chemical components, and potentially affecting the perceived quality of the laundered garments.

Capital costs: The relatively large purchase and installation costs of a wastewater recycling system are likely to be a significant barrier to adoption, regardless of the estimated payback period.[8]

Space Limitations: Wastewater recycle systems can require up to several hundred square feet of floor space and most central laundry areas don't have excess space available.

Low utility costs: Inexpensive utility rates, particularly natural gas, water and wastewater, will create less financial incentive for installing a wastewater recycle system. Similarly, facilities with relatively small laundry throughput may not use enough energy or water to warrant an investment in wastewater recycling technologies. The lower a facility's utility costs, the longer the payback period for the investment.

Resistance from detergent chemical suppliers: In many commercial laundry facilities, the detergent chemical suppliers are responsible for setting up and adjusting the wash cycle programs as necessary to maintain desired levels of cleaning performance over the lifetime of the equipment. After the initial installation of clothes washer equipment, the chemical supplier maintains a high level of interaction with the on-site laundry staff and the physical equipment on an ongoing basis. Many detergent chemical suppliers charge for their service on the basis of the quantity of chemicals consumed. Altering the laundering process usually results in a change to the chemical formulation applied by the detergent providers and may create a direct business conflict with one of the key stakeholders involved in maintaining the smooth operation of the overall laundry system.

Disinfection concerns: Although multiple stages of disinfection are utilized in the wastewater recycling system, a facility manager may be reluctant to deviate from the traditional methodology of using high-temperature wash water for long periods of time to achieve sanitization.

Health and safety concerns: A properly functioning wastewater recycling system with appropriate safety controls poses little to no additional health or safety risks to the on-site laundry staff. However, failure to

[8] Implementation of the AquaRecycle™ system at the Grand Hyatt Seattle included an incentive of $39,620 from Seattle Public Utilities.

provide adequate health and safety information to the facility management and on-site laundry staff may result in health and environmental concerns.

One more stakeholder in a crowded room: Finally, the installation of a wastewater recycling system introduces at least one more stakeholder (the equipment manufacturer and the on-going service provider) to an already crowded process involving numerous stakeholders, including:

- General management of the organization
- Laundry facility manager
- On-site laundry workers
- Machine equipment manufacturer
- Machine maintenance provider
- Detergent chemical provider

The successful operation of a commercial laundry facility requires regular interaction and communication among all these stakeholders and an alignment of business goals and objectives. Resistance to adding yet another critical link to this system may create an intangible, yet real, barrier to adoption.

XI. Recommendations for Advancing the Technologies

Based on the barriers to adoption described above, the team recommendations the following for advancing the adoption rate of wastewater recycling systems:

Targeted outreach campaign: Increase overall knowledge and familiarity by targeting organizations with information regarding the benefits of wastewater recycling performance benefits. Such organizations are likely to have members that operate large, high-throughput laundry facilities with high combined water/sewer costs and high hot water heating costs would have the greatest financial incentives for installing wastewater recycle systems. The targeting of small facilities (those with less than 1,500 pounds of laundry throughput per day) should be limited, as the laundry volumes may not be high enough to warrant the high capital investment.

Simple financial feasibility calculator: Not all commercial laundry facilities are ideal candidates for wastewater recycling installations. As such, product brochures that promise unrealistic savings and financial payback may be met with skepticism, even from facilities that may be ideal target installations sites. To add legitimacy, transparency, and broaden the reach of marketing claims, a simple online calculator should be developed that can be used to determine if the technology is viable for a given laundry facility. The inputs to the tool should include "easily knowable" characteristics such as current laundry equipment type, laundry cycle types, daily laundry throughput, hot water heating fuel type, and local gas, electricity, water, and sewer rates. Such a tool would provide a laundry facility manager with a customized, legitimate estimate of potential energy and water savings potential.

Rebates from local utilities: As demonstrated in this report, wastewater recycling systems can provide significant savings. Utility rebates could incentivize the installation of these systems, particularly for medium- and large-size laundry facilities where the payback period is favorable but high capitals costs may still prove to be too much of a barrier.

Greater collaboration between wastewater recycling system manufacturers and washer manufacturers: Commercial washer manufacturers are primarily large, national/multi-national companies that have been in business for decades. Wastewater recycling system manufacturers are small, regional companies that are relatively new to the market. Collaboration between the two could provide a competitive advantage for washer manufacturers providing efficient technology packages, as well as, increased market share for wastewater recycling installations.

XII. References

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XIII. Appendices

A. Abbreviations and Acronyms

BBA	Better Buildings Alliance
Btu	British thermal units
CBEA	Commercial Building Energy Alliance
DOE	U.S. Department of Energy
kgal	thousand gallons
klb	thousand pounds
kWh	kilowatt hours
MLW	Multi-load washer
PNNL	Pacific Northwest National Laboratory

B. Research Details

Grand Hyatt Seattle Water Recycle Metering and Evaluation Monitoring Plan

Background

Over the past 15 years PNNL has completed a number of high-performance clothes washer analyses, evaluations, and demonstrations. This body of work has included extensive end-use metering of high-performance clothes washers located at coin-operated laundromats, apartment complexes, and in military barracks. Additional evaluation work was completed at a major hotel chain where an ozonation technology was demonstrated and evaluated.

This program is designed to evaluate a laundry water recycling system as installed at the Grand Hyatt in Seattle, WA. The Grand Hyatt, a four diamond hotel located in downtown Seattle, has 425 guest rooms, 3 restaurants, and over 25,000 square feet of conference space.

Included in the Grand Hyatt's facility function is a dedicated commercial laundry operation. This operation makes use of five hard-mount Alliance Laundry/Speed Queen commercial washers: two 165 lb., two 135 lb., and one 55 lb. This equipment serves the laundry needs of all guest-rooms (towels, sheets, etc.) and conference rooms (table linens, etc.).

The goal of this demonstration was to evaluate the energy and water use, saving, and economics of commercially available water recycle system. The equipment to be evaluated was manufactured by Aqua Recycle of Marietta, GA and was retrofit to the Grand Hyatt Seattle's existing laundry operation in the winter of 2012/2013.

Scope

This evaluation made use of a combination of field-measured variables and, where available, utility billing data as a confirmation.

Field performance evaluations relied on a combination of electronic data collected by the washer (some, not all, washers collect a variety of use statistics) and data collected by external metering devices. Once collected, these data served as the basis for component operation performance, use (i.e., cycles-per-day) verification, and overall performance validation. Elements of the field performance monitoring protocol are included below.

Customer/operator satisfaction was requested at the mid-point and the end of this study. Site staff will be asked for input on system operation, performance, maintenance needs, and overall satisfaction.

Field Performance Monitoring Protocol

Because this recycling system is existing (i.e., has already been installed), the protocol will include and analysis to account for the savings from a "technical" baseline. This baseline was developed using additional metering to measure temperatures and flow rates of system-return water. In a true baseline this water would have been supplied by makeup water, at make-up water temperatures. As such, the volumetric flow and the embodied energy of this system-return, serves as the energy benefit to the installation.

The specific project objectives are listed below:

- Evaluate hot/cold water and *energy use* for the Aqua Recycle laundry waste water recycling system, including the development and calculation of the technical baseline.
- Evaluate hot and cold water and *energy saving* associated with the Aqua Recycle laundry waste water recycling system.
- Evaluate clothes washer utilization (average cycles and/or pounds washed per period).
- Present the water, energy, and economic findings.

Monitoring Plan

The system monitoring points were selected based on ease of access, ease of metering equipment installation, and willingness/interest of owner and users to assist. We anticipate collecting data for at least 2 months to ensure all variables of operation are accounted for. Monitoring may go beyond the 2-month window if needed.

A description of each monitored parameter is included below. Monitoring took place at the recycling system where water flow, water temperature, and electrical energy will be monitored. All monitored data was supplied to data loggers for data storage and eventual download for analysis.

System Water Temperature: Water temperature was monitored using thermocouple data loggers affixed to the warm supply (from the recycling system) and the cold makeup water. The thermocouples provided the temperature data to the data logger where it was stored in a time-series format. Each cold makeup water point (two in total) had at least one thermocouple attached to the water supply piping.

System Water Use: Water use was monitored by non-intrusive ultrasonic flow meters at two locations:

- Cold make-up supply to the water -recycle system
- Warm outlet (water-recycle system) supply to heat exchanger

The water meters were installed on the 2- or 3-inch copper supply lines. This is a proven installation technique and, because it does not affect existing piping (i.e., the meters reside on the exterior of the piping), it eliminates the need for a plumber's intervention. The meters provided a continuous data use record of water flow to the data logger where it was stored in a time-series format.

An additional water flow monitoring point was an existing in-line Onicon flow meter measuring cold make-up to the washers for rinsing purposes. While this point was monitored, it did not affect the performance of the recycle system as this water supply doesn't change as a result of the AquaRecycle system installation.

System Electrical Energy Use: Electrical energy use (recycle-system electricity for pumps, motors, shaker/lint system, UV light, and all controls) was monitored by a watt transducers installed at the serving electrical panel. The watt transducer provided pulse-output wattage data (pulses calibrated to a known kWh value) to the data logger where it was stored in a time-series format.

System (Clothes Washer) Utilization: The total number of cycles per machine and/or pounds of laundry washed were captured at the clothes washer by the on-board washer tracking software and/or site staff. Site staff tracked, downloaded, and reported these values on a weekly basis.

Data Collection and Storage: The data logger used to record and store the temperature, energy, and water use data was downloaded on-site at an interval based on system use and data storage capability. Figure 9 illustrates the metering points.

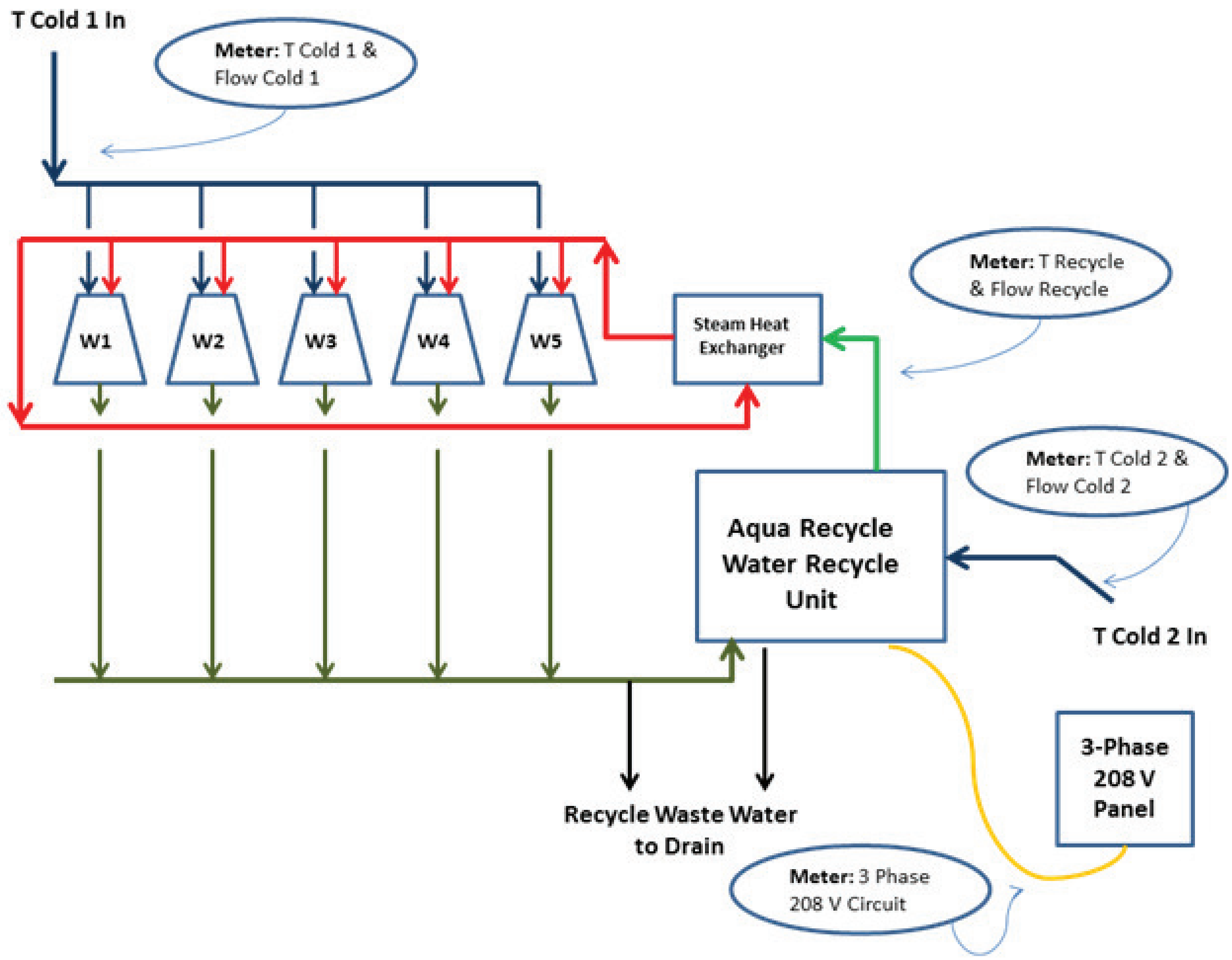

Figure 9. Hyatt Clothes Washer Recycle Metering Equipment and Points

Metering Equipment Pictures:

Figure 10. Installation of Watt Meter in Electrical Panel serving the AquaRecycle System (Photo: Efficiency Solutions)

Figure 11. Ultrasonic Flow Meter as Installed on Recycled Water Piping (Photo: Efficiency Solutions)

Figure 12. Ultrasonic Flow Meter Output and Data Logging System (Photo: Efficiency Solutions)

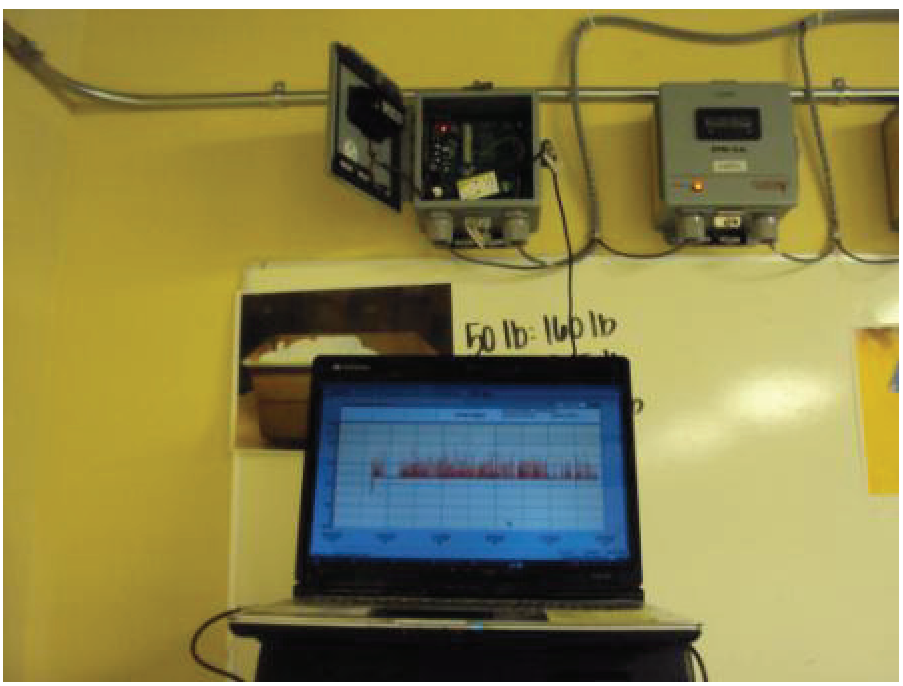

Figure 13. Data Downloading from Existing Flow Meter System (Photo: Efficiency Solutions)

C. Weight Normalized Calculations

$$Monthly\ elec.impact\ \ (\$/klbs) = \frac{\sum Monthly\ elec.use\ (kWh)}{\sum Monthly\ laundry\ washed\ \ (klbs)} \times Elec\ rate\ (\$/kwh)$$

$$Monthly\ water\ impact\ \ (\$/klbs) = \frac{\sum Monthly\ water\ savings\ (kgal)}{\sum Monthly\ laundry\ washed\ \ (klbs)} \times water\ rate\ (\$/kgal)$$

$$Monthly\ hot\ water\ impact\ \ (\$/klbs) = \frac{\sum Monthly\ hot\ water\ savings\ (therms)}{\sum Monthly\ laundry\ washed\ \ (klbs)} \times hot\ water\ rate\ (\$/therm)$$